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Financial Evaluation of Smallholder Timber-based Agroforestry Systems in Claveria, Northern Mindanao, the Philippines

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In the Philippines, timber production on small farms has become profitable as a result of reduced supplies due to extensive deforestation and increasing demand. In the early 1990s, when the price of timber was high, farmers were promised huge returns from tree farming. However, widespread planting of few species has led to oversupply and a sharp decline in the price of farm-grown timber. Moreover, low intercrop yields as a result of competition from fast-growing trees and low timber yields due to poor tree management, further reduce net economic returns. In spite of this, interest in tree farming remains high. This paper examines the private profitability of two tree-maize systems, namely trees in *blocks* and trees in *hedgerows*, compared with the alternative of maize monocropping. The analysis reveals that maize monocropping provides higher returns to land at the current timber price, but considerably lower returns to labour, than the maize-tree systems tested. This suggests that tree farming is a more attractive option for labour and capital-constrained households or those with off-farm opportunities that compete for their labour. These farmers may raise productivity and income by planting trees on the excess land that cannot be devoted to annual crops. The analysis also indicates that wide-spaced tree hedgerows are superior to tree blocks, due to lower establishment and management costs, longer periods of viable intercropping and more rapid tree growth.

Keywords: financial assessment, land expectation value, returns to labour, tree farming, tree intercropping

INTRODUCTION

In the late 1980s, diminishing timber supplies from natural forest and strong market demand led to an increase in the price of timber in the Philippines. Farmers seized this economic opportunity by planting fast-growing trees, including *Gmelina arborea* R. Br (gmelina), *Paraserianthes falcataria* (L.) Nielsen (falcata), and *Acacia mangium* Willd. (mangium), as a cash crop (Garrity and Mercado 1994). Tree planting has become so widespread that farm forestry has been proposed as a viable alternative to expensive government-driven reforestation projects (Pasicolan

et al. 1997). Presently, planted trees account for an increasingly important share of the Philippine wood industry output (ITTO 2001).

Since the emergence of farm forestry as an economic option for farmers, government extension agencies have been promoting tree planting as an exceptionally profitable farm enterprise. This promise was based on overoptimistic timber yields[1] of fast-growing trees and the high timber price prevalent in the past. Unfortunately, by the mid-1990s, as many planted trees reached harvestable age, timber prices fell drastically due to market saturation. In 1997, the stumpage price of gmelina timber averaged PhP4/board foot (bf), a 60% decline compared with the price in the late 1980s. This price fall caused disenchantment among upland farmers (Caluza 2002).

The low price of farm-grown timber is not the only reason for diminishing returns from tree farming systems. When fast-growing timber species are planted on farms, tree competition for above- and below-ground resources reduces yields of intercrops below economic levels as early as one year after tree planting. Furthermore, severe pruning to control tree competition effects and the lack of thinning in woodlots due to farmers' reluctance to remove immature trees, reduce timber yield and quality (Bertomeu 2004).

In spite of these setbacks, interest in tree farming continues to be high. Although dissatisfied with price, gmelina planters in Claveria are still interested in growing this species because of economic returns from harvested timber, animal weight gain, and ecological benefits including enhanced soil fertility, soil erosion control and windbreak effects (Magcale-Macandog and Rocamora 1997, Magcale-Macandog *et al*. 1999). Many smallholders are also willing to plant *Eucalyptus deglupta* Blume (bagras) and *Swietenia macrophylla* King (mahogany), even if rotations are longer than that of gmelina, because of their compatibility with associated crops and the higher market price of these timbers. Elsewhere, economic analyses suggest that planting timber trees may be also a more attractive option for labour-constrained farming households because maximising returns per unit of labour would be their primary concern (Netting 1993, Arnold and Dewees 1997, Franzel and Scherr 2002). In the Philippines, tree farming would also be more financially attractive than maize monocropping, the dominant agricultural system in the uplands, in the event of an increasing farm labour wage as the economy diversifies and more rural people find work off-farm (Coxhead and Jayasuriya 2001). These labour-constrained farmers may supplement their incomes by planting trees on excess land that cannot be put under annual crops (Midmore *et al*. 2001). Even on smaller farms with a priority on crop production, planting timber trees on boundaries away from crops or at low densities seems to be an attractive option to enhance income (Bertomeu 2004).

In this paper, the profitability of two tree-maize systems − trees in block arrangement (2 x 2.5 m) and trees in hedgerow (1 x 10 m) − are compared with maize monocropping. It was hypothesised that agroforestry systems with widely-spaced tree hedgerows would be more profitable than systems with closely-spaced trees (blocks). In the former, the cropping area lost to trees is minimal, intercropping is viable for longer periods, tree establishment and management costs are lower, and

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[1] For example, a local newspaper reported that one *Eucalyptus deglupta* tree would yield 1.5 m^3 (636 board feet) of lumber in 10 years and produce returns of PhP14,000/tree or PhP10.5 M/ha, or US$400,763/ha at the 1996 exchange rate of US$1 = PhP26.2 (Fonollera 1996).

trees grow faster and timber yields per tree are higher because of the more intensive management and favourable light regime.

The next section provides an overview of the study site, which sets the context for this analysis. The research methods and the maize and timber yield data used in the financial analysis are then reported. Next, the returns to land and returns to labour are reported for the systems studied, including a sensitivity analysis. The paper concludes with policy implications and suggestions for further research that will support the development of smallholder tree farming systems.

THE STUDY SITE

The study was conducted in Claveria, an upland municipality located 42 km northeast of Cagayan de Oro City, the capital of the province of Misamis Oriental in northern Mindanao, the Philippines (8^{o} 38' N, 124^{o} 55' E) (Figure 1). The municipality covers an area of 112,175 ha, and has a mountainous topography with 62% of the area having slopes of 18% or greater and elevation ranging from 390 to 2000 masl (DTI and PKII Engineers 1996). Soils are derived from volcanic parent material and classified as deep acidic (pH 3.9-5.2) oxisols with texture ranging from clay to silty clay loams, with low available phosphorus (P), low carbon exchange capacity (CEC), high aluminium (Al) saturation and low exchangeable potassium (K) (Magbanua and Garrity 1988). The average rainfall is 2500 mm, with a wet season (with precipitation of more than 200 mm/month) from June to December and a short dry season (less than 100 mm/month) in March and April (Kenmore and Flinn 1987). Temperatures exhibit little variation throughout the year, with an average maximum of 28.6 °C and average minimum of 21.3 °C.

At lower elevations (400 to 700 masl), maize (*Zea mays* L.) is the dominant crop, cultivated twice a year or in rotation with cassava (*Mahinot esculenta* Crantz) or upland rice (*Oryza sativa* L.). Typically, a wet season crop planted on the onset of the rainy season (May) is followed by a dry season crop planted in September or October. Tomatoes and other vegetable cash crops are commonly grown on the higher elevations (700 to 900 masl). The average farm size is 2.5 to 3 ha with farmers commonly cultivating two or more parcels of land.

In the past 50 years, land use in Claveria has experienced a rapid transformation from natural forests to grasslands and then to a mosaic of intensive cash and food cropping and perennial-based systems (Garrity and Agustin 1995). Recently, the use of narrow grass strips along contours as a measure to control soil erosion, a practice known as natural vegetative strips (NVS), has become common among farmers in the area. This practice is also the basis for the incorporation of fruit and timber trees (Stark 2000).

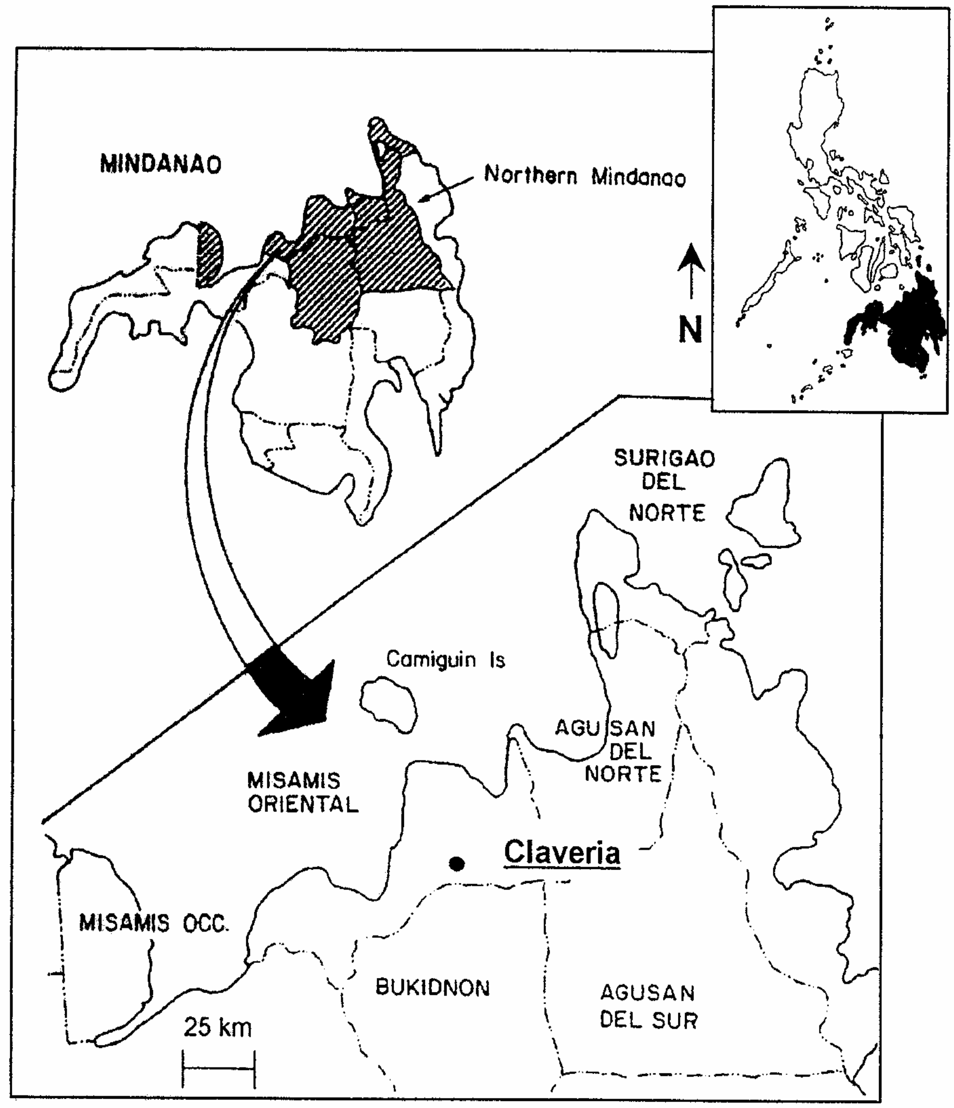

Figure 1. Location of the study site in Northern Mindanao, Philippines

Source: Stark (2000).

RESEARCH METHOD

Data on tree growth and maize yield used in the financial analysis were collected from on-farm experimental plots established to study maize-timber intercropping systems. The experimental set-up consisted of researcher-designed and -managed on-farm trials with plots laid out in a randomised complete block design with three treatments and four replications. Two timber species were used in association with maize: gmelina and bagras. Treatments were:

- T_1 (Control): maize monocropping between three contour grass strips (NVS) established 10 m apart. Fifteen rows of maize were planted on each of the two alleys between the NVS.
- T_2 (Block planting): timber trees in block arrangement at 2 x 2.5 m, i.e. 2000 stems per hectare (sph), with 9 lines of trees on NVS with 8 trees per line (i.e. 72 trees), and 3 rows of maize inter-planted in each of the 8 2.5 m alleys until canopy closure (Figure 2).
- T_3 (Hedgerow planting): timber trees on hedgerows at 1 x 10 m (1000 sph), with 3 lines of trees on NVS with 16 trees per line (i.e. 48 trees), and 15 rows of maize interplanted in the each of the two 10 m wide alleys (Figure 3).

All plots were 300 m^2 (15 x 20 m), with a centred net plot (maize sampling plot) of 6 m, a border of 4.5 m on both sides of the net plot, and a guard area of 8 to 9 m between plots to avoid influence on observations of trees from adjacent plots. The slope of the experimental plots ranged from 20 to 30%.

Tree seedlings were raised for about three months in a nursery at Claveria until they were 25 to 30 cm tall. In September 1997, NVS were established in the research plots during land preparation by leaving a 50 cm wide unploughed strip along the contour. Then, tree seedlings were planted at the trial sites just above the NVS. Dead trees were replaced until the end of December 1997. From January to May 1998 trees were watered twice a month because of a severe drought. After the drought, failed seedlings were replaced to keep plot conditions homogenous. These newly planted trees were not included in the calculations of tree growth and yield.

Maize cropping commenced in October 1997 (2nd crop 1997), immediately after tree planting, and continued for seven cropping seasons in the control and hedgerow treatments, and for three cropping seasons (until canopy closure) in the block treatment. Every year, a wet season maize crop was planted in May and harvested in early September, followed by a dry season crop sown in early October and harvested in January. Following local practice, draft animal power was used for land preparation, consisting of two ploughing and one harrowing operation. All other maize farming operations (i.e. fertilizing and weeding) were performed manually.

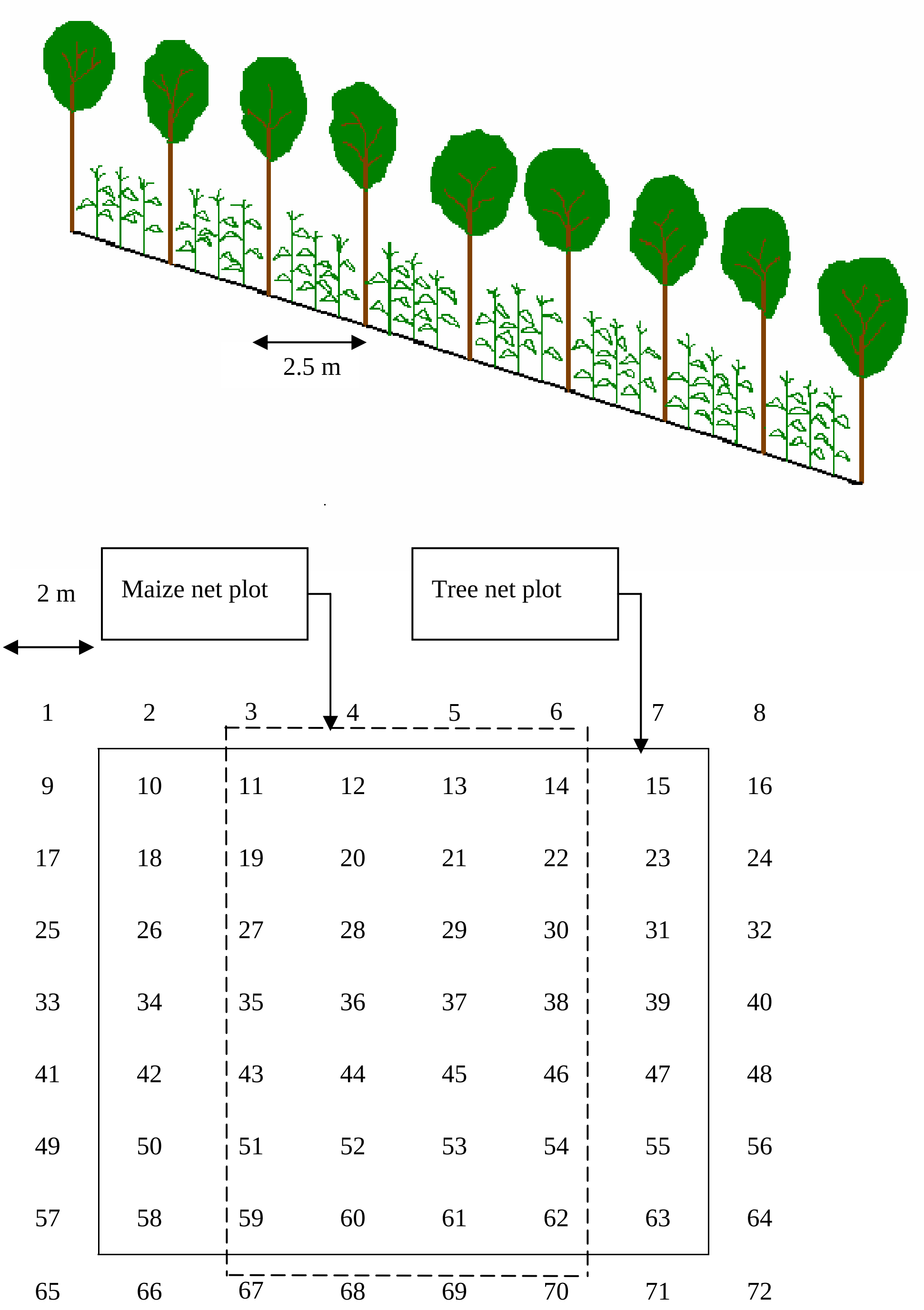

Figure 2. Layout of tree-maize experimental plot in block arrangement

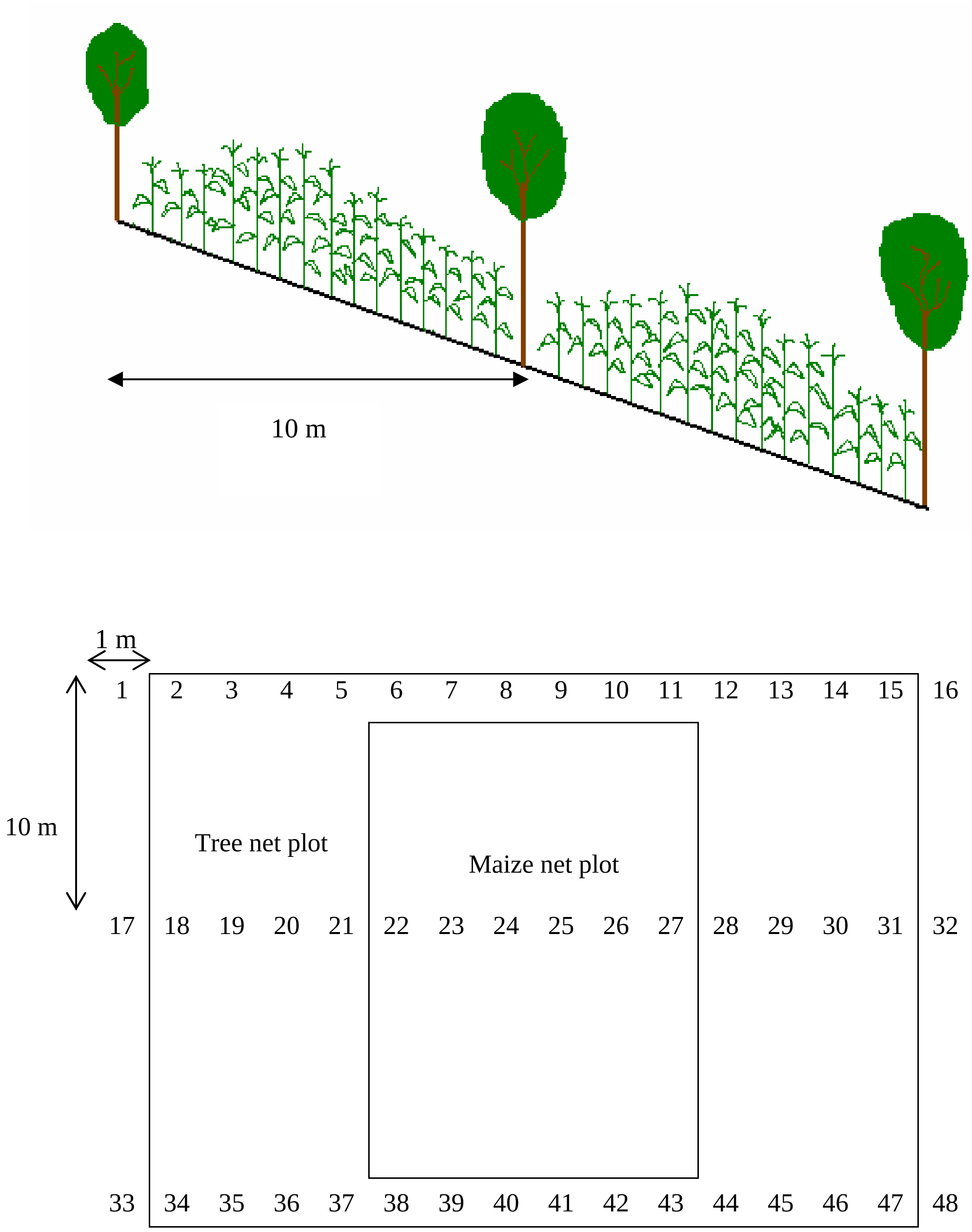

Figure 3. Layout of tree-maize experimental plot in hedgerow arrangement

Every cropping season, the hybrid maize variety Pioneer 3014 was sown into furrows at a spacing of 30 cm along each row and 60 cm between rows. Each maize crop was fertilized with the recommended dose of 80-30-30 kg NPK/ha. Phosphorus (Solophos 0-18-0) and potassium (Muriate of Potash 0-0-60) fertilizer and the insecticide-nematicide Furadan 3G were applied at sowing. Maize re-sowing was carried out 5 to 7 days after emergence (DAE). Nitrogen (Urea 46-0-0, 46% N) was

applied as equal split doses by side dressing 15 and 30 DAE. After nitrogen application, interrow cultivation was performed to cover the fertilizer with soil and as a weed control measure. Fertilizer was applied only to the crop as described above. However, trees have probably benefited from the fertilizer applied to the maize. Hand weeding of the maize crop was also done as needed, usually one to two weeks after the second interrow cultivation.

Lime (calcium carbonate, $CaCO_3$) was applied at the rate of 3 ton/ha to all plots before the third cropping season (September 1998), because maize growth in a portion of the net plot of one hedgerow plot and one control plot was severely affected by soil acidity, showing aluminium-induced symptoms of magnesium (Mg) deficiency. Before the sixth cropping season (May 2000), lime was applied again at the rate of 2 ton/ha on the research plots located at Ane-i. Lime was applied at the rate recommended by Von Uexkull (1986) and Ahn (1993) of 1.5 to 2.0 t/ha of CaCO3 for every 1 milli-equivalent/100 g of exchangeable Al, based on a soil depth of 15 cm.

Ringweeding around planted tree seedlings was conducted at planting. Subsequent weeding consisted of two grass slashing operations per cropping season for trees in hedgerow plots. Trees in block plots were weeded only through the third year.

One ‘singling’ and form pruning was conducted to retain a single stem and improve form when the trees were one year old. Branch pruning was performed three times during the four-year study period, with the aim of leaving a live crown ratio (LCR) of 40 to 60%. A 50% intensity thinning was conducted at 34 months after planting, leaving 1,000 sph in the block treatment and 500 sph in the hedgerow treatment.

Maize grain yield data were collected row by row from the 6 m wide centred net plot. At harvest, fresh grain and total biomass were measured and two plant samples taken from each of the upper, middle and lower alley zones. Grain yield at 14% moisture content was obtained after oven-drying a sub-sample.

Diameter at breast height (dbh) and tree height were recorded twice a year until age 54 months. At age 40 and 48 months, diameter at a height of 2.4 m was also recorded to calculate taper (measured as cm of change in diameter for each m of length).

Maize and Timber Yield

Financial calculations were made for a tree rotation period of eight years for agroforestry systems with gmelina and 12 years for bagras. Maize yield used in the financial analysis from years 1 to 4, for each treatment, was the average over replications and excluded the area occupied by the NVS. Although the first maize crop in the experimental plots began in the dry season of 1997 (October), financial calculations included the maize grain yield for the wet season crop of 1997 (May), assumed to be the same in all treatments and equal to the average yield of the maize monocropping treatment (4.9 t/ha for systems with gmelina and 5.6 t/ha for systems with bagras) (Tables 1 and 2).

Table 1. Maize grain yield in the two agroforestry systems with *Gmelina arborea* and under maize monocropping (t/ha)

Year	Wet season crop			Dry season crop		
	Maize monocrop	Maize-tree hedgerow	Maize-tree block	Maize monocrop	Maize-tree hedgerow	Maize-tree block
1	4.90[a]	4.90[a]	4.90[a]	2.95	2.72	3.01
2	5.68	4.82	4.97	2.48	*1.71*	*0.32*
3	4.61	*2.55*	-	3.17	*1.38*	-
4	4.51	*2.45*	-	2.81	*0.95*	-
5-8	4.90	-	-	2.90	-	-

a. Financial calculations included the maize grain yield for the first wet season crop (May 1997), assuming yield to be the same in all systems and equal to the average wet season crop in the maize monocropping plot.
Yields below the break-even are written in italics.

Table 2. Maize grain yield in the two agroforestry systems with *Eucalyptus deglupta* and under maize monocropping (t/ha)

Year	Wet season crop			Dry season crop		
	Maize monocrop	Maize-tree hedgerow	Maize-tree block	Maize monocrop	Maize-tree hedgerow	Maize-tree block
1	5.6[a]	5.6[a]	5.6[a]	3.41	3.37	3.20
2	6.87	6.30	5.65	3.20	3.09	*1.57*
3	5.31	4.01	-	4.05	2.59	-
4	4.75	3.70	-	3.01	*1.74*	-
5-12	5.60	-	-	3.4	-	-

a. Financial calculations included the maize grain yield for the first wet season crop (May 1997), assuming yield be the same in all systems and equal to the average wet season crop in the maize monocropping plots.
Yields below the break-even are written in italics.

Timber yields scenarios at harvest are presented in Table 3. For both species and agroforestry regimes, the final tree crop was assumed at 250 sph, as recommended by DENR-ERDB (1998) and the GOLD Project (1998). The average dbh at harvest in the 'low' and 'high' timber yield scenarios were determined based on the dbh growth of trees in the experimental study and literature reports. In the experimental plots, the mean annual increment (MAI) in dbh for gmelina over a 4-year period was 4.7 cm/yr for trees in the hedgerow system and 4 cm/yr for trees in blocks. These are within the range of MAI (3.3 to 5 cm/yr) for average sites reported by DENR-ERDB (1998). For bagras, the mean annual growth in dbh over the same period was 3.4 cm/yr for trees in hedgerows and 3.1 cm/yr for trees in blocks. At the end of the study, the dbh observations of bagras were similar to those reported by Tomboc (1976) for PICOP plantations of the same age (13.6 and 14.9 cm). In both species, the difference in average dbh between 4.5 year-old trees in the hedgerow and block

treatments increased with age, although only gmelina provided convincing evidence that trees planted in hedgerows attain a greater dbh than trees planted in blocks. The average dbh of gmelina in the hedgerow system was 16% greater than in blocks (19.9 vs 17.1 cm). For bagras, the average dbh of trees in hedgerows was 14% greater than in blocks (15.6 vs 13.7 cm). Sawmill owners interviewed reported a minimum merchantable small-end diameter at harvest of 14 cm. With this information and the taper found in this study − 2 cm/m for gmelina in hedgerows, 1.5 cm/m for gmelina in blocks, and 0.8 cm/m for bagras in both arrangements − the merchantable height at harvest was estimated. Estimates of dbh and merchantable height at harvest were validated, in the case of gmelina, with measurements taken on 175 harvested logs and interviews with 16 sawmill operators. It was not possible to take these measurements on bagras because most planted trees in the study area had not reached maturity. Finally, existing tree volume equations were used to calculate timber volumes at harvest in the 'low' and 'high' timber yield scenarios (Table 3). Estimated yields for gmelina and bagras in the low productivity scenario are similar to those used by DENR-ERDB (1998) in financial analyses of plantations of the same species.

Table 3. Harvest scenarios for *Gmelina arborea* in an 8-year rotation period and *Eucalyptus deglupta* in a 12-year rotation period

Timber yield scenario		Stocking density (sph)	Tree hedgerows (1 x 10 m)			Tree blocks (2 x 2.5 m)		
			Dbh (cm)	H_m (m)	V_m (m^3/ha)	Dbh (cm)	H_m (m)	V_m (m^3/ha)
G. arborea	Low	250	30	8.6	69	27	9.1	61
	High	250	35	11.0	110	32	12.3	104
E. deglupta	Low	250	28	15.0	146	28	15.0	146
	High	250	30	17.0	185	30	17.0	185

H_m: merchantable height, assuming a small-end diameter of 14 cm and taper.
V_m: merchantable volume, estimated with the tree volume equations:
Log Vm = -3.8579 + 1.6844 log Dbh + 0.8671 log Hm, for *G. arborea* (Virtucio 1984), and .
Log Vm = 0.030318 + 2.049154 log Dbh + 0.739098 log Hm, for *E. deglupta* (Tomboc 1976).

Cost and Labour Data

Table 4 presents input and labour costs of maize monocropping and maize-gmelina intercropping. The unitary costs for maize-bagras intercropping are the same except for seedling costs. Cost of inputs and labour and prices of projects correspond to 1998 values using local prices. The value of family labour used is the average agricultural wage rate of Claveria in 1998 (PhP60/man day and PhP120/man-animal day) (Bertomeu 2004). Land value was assumed to be equal for the three systems and thus was not included in the analysis. Timber harvesting and transportation costs were not included in the financial calculations, because farmers in Claveria commonly sell timber on stump. Because of the important bias introduced when estimating labour use from small-sized research plots, labour data for all the activities involved in maize cultivation, including the slashing of contour grass strips, were taken from Nelson *et al*. (1996). Labour use for tree establishment (hole

digging, planting and weeding) and management (pruning and thinning) was derived from various sources (including Agpaoa *et al*. 1976, Laarman *et al*. 1981, Pancel 1993, DENR-ERDB 1998), and by interviewing farmers immediately after the task was completed (for tree pruning only). No major differences in the cost of tree management were observed between hedgerow and block planting systems except for the fact that three prunings and two thinnings are considered to be required in the hedgerow arrangement and two pruning and three thinning operations in the block arrangement.

Table 4. Input and labour costs of maize monocropping and maize − *Gmelina arborea* intercropping (US$)[2]

Input	Maize monocropping		Maize-tree hedge-row (1 x 10 m)		Maize-tree block (2 x 2.5 m)	
	Md/ha[a]	Cost/ha	Md/ha[a]	Cost/ha	Md/ha[a]	Cost/ha
Layout hedgerows	3	4	3	4	7	11
Tree seedlings[b]		-		30		60
Subtotal 1		4		34		71
Non-labour maize cultivation (per crop)						
Seeds[c]		34		34		27
Solophos fertilizer[d]		62		62		49
Potash[d]		10		10		8
Furadan[e]		21		21		17
Nitrogen fertilizer[d]		27		27		21
Subtotal 2		153		153		123
Labour maize cultivation (wet season)						
Land preparation[f]	22	67	22	67	18	53
Maize sowing and fertilizing at planting	5	8	5	8	4	6
Replanting	2	3	2	3	2	3
Nitrogen fertiliser	6	10	6	10	5	8
Interow weeding[f]	3	10	3	10	3	8
Hand weeding (corn)	17	25	17	25	14	20
Hedgerow grass slashing[g]	10	15	10	15	28	42
Maize harvesting	12	17	12	17	9	14
Post-harvest processing	20	30	20	30	16	24
Subtotal 3		185		185		178
Labour maize cultivation (dry season)						
Land preparation[f]	13	38	13	38	10	31
Maize sowing and fertilizing at planting	5	8	5	8	4	6
Replanting	2	3	2	3	2	3
Nitrogen fertiliser	6	10	6	10	5	8
Interow weeding[f]	3	10	3	10	3	8
Hand weeding (corn)	13	19	13	19	10	15
Hedgerow grass slashing[g]	10	15	10	15	28	42

[2] An exchange rate as in 1998 of US$1 = 40PhP has been adopted for the financial analysis, obtained from: exchange rate_1990-2002 www.bsp.gov.ph/statistics/exrate/usd/year_htm).

Table 4 (cont.)

Input	Maize monocropping		Maize-tree hedge-row (1 x 10 m)		Maize-tree block (2 x 2.5 m)	
	Md/ha[a]	Cost/ha	Md/ha[a]	Cost/ha	Md/ha[a]	Cost/ha
Maize harvesting	12	17	12	17	9	14
Post-harvest processing	13	19	13	19	10	15
Subtotal 4		139		139		137
Tree establishment						
Hole digging	-	-	17	26	34	51
Planting and replanting	-	-	12	18	24	36
Tree weeding[h]	-	-	13	19	25	38
Subtotal 5				62		125
Tree management						
Slashing of weeds[i]	-	-	5	30	14	84
Form pruning and singling	-	-	1	2	2	3
First lift pruning	-	-	6	9	13	19
Second lift pruning	-	-	5	8	5	8
Third lift pruning	-	-	5	8	-	-
First thinning	-	-	0.5	1	1	2
Second thinning	-	-	0.5	6	1	7
Third thinning	-	-	-	-	1	7
Subtotal 6				63		129

Notes:
Cost of inputs are from local markets for the 1998 cropping season. Labour is costed at the local farm wage rate in 1998. A work-day is assumed to involve 8 hours of work.
a. Md/ha: Man-day per hectare. Labour cost PhP60/man-day.
b. Tree seedlings cost: *Gmelina arborea* = PhP1/seedling; *Eucalyptus deglupta* = PhP3/seedling. A mortality rate of 20% has been assumed.
c. Maize seed rate: 60,000 plants/ha. Maize seed cost: PhP75/kg.
d. Fertilizer: recommended rate is 80-30-30 kg of NPK/ha; Nitrogen (Urea 46-0-0, 46%N) at PhP7/kg; Phosphorus (Solophos 0-18-0) at PhP6/kg; Potassium (Muriate of Potash 0-0-60) at PhP7/kg.
e. Insecticide-nematicide Furadan applied at sowing at a rate of 16 kg/ha. Furadan purchased at PhP70/kg.
f. Man-animal-day/hectare, and a cost of PhP120/man-animal-day.
g. Two grass slashing of NVS during each cropping season.
h. One tree ring-weeding and cultivation at planting.
i. It is assumed four grass slashings around trees from the last cropping season through to the end of year, three in those systems in which maize intercropping is discontinued before the end of year 3 (i.e. in gmelina in hedgerow and block arrangements, and in bagras in blocks).

Financial Analysis of Smallholder Maize-agroforestry Systems

The financial net benefits of the tree farming and maize monocropping systems have been assessed in terms of land expectation value (LEV) per hectare. The LEV is the present value of the income from an infinite sequence of harvests, and it represents the value of bare land if used to grow trees. The LEV is useful to compare forestry investments of different rotations, or investments of totally different land uses, e.g. comparison of forestry where income is delayed and agricultural crops where income is received yearly. The analysis also includes a calculation of the net returns to labour, because, as noted by Franzel *et al*. (2002), this indicator is relevant for

labour-constrained farmers or those with off-farm income-earning opportunities that compete for their labour. Returns to labour have been estimated as:

Returns to labour = Discounted net benefits to labour (1) / Discounted labour days (2)

$(1) = \sum_{j=1}^{n} \left[\left(B_j - I_j \right) / \left((1+r)^j - 1 \right) \right]$, where B_j = benefits in year j, j = 1, 2,…, n,

and I_j = input costs in year j, j = 1, 2,…, n.

$(2) = \sum_{j=1}^{n} \left[WD_j / \left((1+r)^j - 1 \right) \right]$, where WD_j = labour work-days.

For each agroforestry system, four scenarios are presented by using low and high timber yields with the current timber price (PhP4/bf) and maize price (PhP4.5/kg wet season crop and PhP5.7/kg dry season crop), and two real discount rates (15% and 20%) The annual discount rates of 15% and 20% were assumed based on the cost of borrowing capital in the study area. Sensitivity analyses were conducted to estimate the effect of variations in labour and output prices, and also the discount rate. The sensitivity of the systems to changes in the values of basic parameters is represented by break-even lines for various pairs of parameter values (timber and maize price), discount rates (10%, 15% and 20%) and timber yields (low and high), following Von Platen (1992).

Financial Performance of Smallholder Maize-timber Agroforestry Systems

The analysis of returns to land for gmelina-maize agroforestry in the low timber yield scenario shows LEVs of maize monocropping 44% to 62% higher than that of tree hedgerows and 57% to 74% higher than for tree blocks (Tables 5 and 6). In the case of high timber yields (104 - 110 m^3/ha), the LEV of gmelina hedgerows is the same as maize monocropping, at a discount rate of 15%, but 15% lower if the discount rate applied is 20%. Maize monocropping is more profitable than any other agroforestry alternative at a 20% discount rate. Therefore, at the current timber price, gmelina intercropping is not as profitable as maize monocropping. Besides its low timber price, the main disadvantage of gmelina is its high competitiveness for site resources. This species reduces maize grain yield below the break-even level after two cropping seasons, even when tree lines are planted at 10 m intervals. The profitability of gmelina tree blocks is found to be lower than tree hedgerows. The benefits of planting trees in hedgerows relative to tree blocks are the reduced costs of seedlings and labour for tree establishment (planting) and management (weeding and pruning).

Table 5. Returns to land and labour of agroforestry with *Gmelina arborea* and maize monocropping over an 8-year tree rotation period

System	Maize (t/ha/9 yr)	Timber (m^3/ha)	Returns to land: LEV (US$/ha)		Net returns to labour: (US$/work-day)	
			r = 15%	r = 20%	r = 15%	r = 20%
Maize monocropping	70.1	0.0	2,278	1,708	3.8	3.8
Low timber yield:						
Tree hedgerow (1 x 10 m)	12.5	69.1	1,581	1,056	5.7	4.9
Tree block (2 x 2.5 m)	12.9	60.8	1,448	979	4.6	4.0
High timber yield:						
Tree hedgerow (1 x 10 m)	12.5	110.6	2,279	1,479	7.4	6.2
Tree block (2 x 2.5 m)	12.9	104.4	2,180	1,422	6.0	5.1

Timber price = PhP4/bf or US$42.4/$m^3$.

A similar pattern of financial performance is obtained for agroforestry with bagras: at current timber prices maize monocropping is more profitable than the agroforestry options studied, even with high timber yields (Table 6). Planting bagras in hedgerows is between 28% and 44% more profitable than in blocks. The benefits of tree hedgerows are lower costs of seedlings and weeding, and higher maize yields because of the longer intercropping period. However, labour inputs and non-labour maize cultivation costs are higher for hedgerow systems than tree block systems.

Even though bagras rotations are four years longer, hedgerows of bagras are approximately 40% more profitable than hedgerows of gmelina in the lower timber yield scenario and 10% to 12% more profitable in the high timber yield scenario. The advantages of bagras over gmelina hedgerows are the higher timber yields (111% higher in the low-yield scenario and 67% in the high-yield scenario) and the longer period of intercropping (four cropping seasons more). There is no great advantage of blocks of bagras over blocks of gmelina. In the low timber yield scenario, blocks of bagras are between 6 to 14% more profitable than blocks of gmelina, only because yields of bagras are almost 2.5 times as high as yields of gmelina. But in the high timber yield scenario, tree blocks with bagras are 10% to 18% less profitable than tree blocks with gmelina.

Table 6. Returns to land and labour of agroforestry with *Eucalyptus deglupta* and maize monocropping over a 12-year tree rotation period

System	Maize (t/ha/12 yr)	Timber (m^3/ha)	Returns to land: LEV (US$/ha)		Returns to labour: net returns (US$/work-day)	
			r = 15%	r = 20%	r = 15%	r = 20%
Maize monocropping	117.3	0.0	3,245	2,433	4.7	4.7
Low timber yield:						
Tree hedgerow (1 x 10 m)	28.7	146.1	2,204	1,495	5.6	4.9
Tree block (2 x 2.5 m)	14.5	146.1	1,656	1,037	5.9	4.8
High timber yield:						
Tree hedgerow (1 x 10 m)	28.7	184.6	2,520	1,662	6.1	5.2
Tree block (2 x 2.5 m)	14.5	184.6	1,972	1,205	6.6	5.3

Timber price = PhP4/bfor US$42.4/$m^3$.

The estimation of returns per hectare of land is relevant when land is scarce. But labour-constrained farmers would be more concerned about maximising the crop return per unit of labour (Arnold and Dewees 1997, Franzel and Scherr 2002). The analysis of returns to labour is more favourable for maize-tree agroforestry in all scenarios, indicating the superiority of timber-based agroforestry systems for labour-constrained farmers whose objective is to maximise land productivity with scarce labour. Over one tree rotation, a hectare of maize-timber agroforestry requires approximately 70 to 80% less labour than a hectare of maize monocropping. Comparisons between agroforestry systems reveal that woodlots of gmelina require 26% more labour than hedgerows because of the greater number of trees in the former (Figure 4). In contrast, because of the extended period of intercropping, bagras planted in hedgerows requires 53% more labour than blocks (Figure 5). Therefore, returns to labour are slightly higher for woodlots of bagras, although the difference declines at higher discount rates.

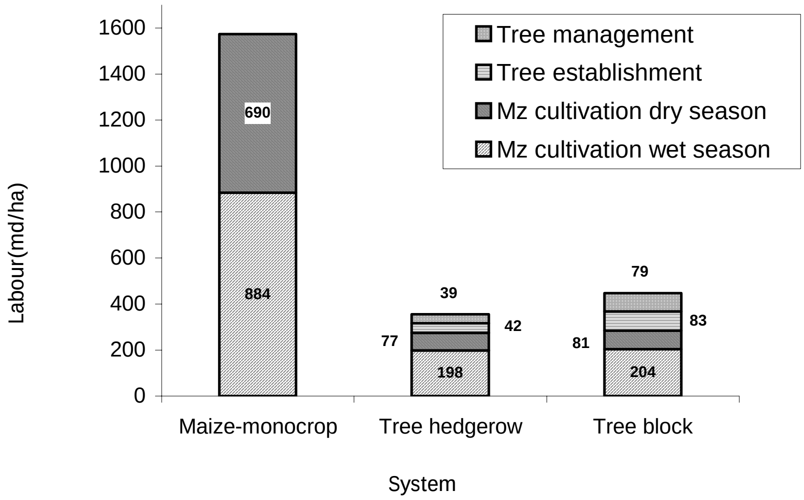

Figure 4. Labour inputs required for maize monocropping and maize-*Gmelina arborea* agroforestry for an 8-year rotation period

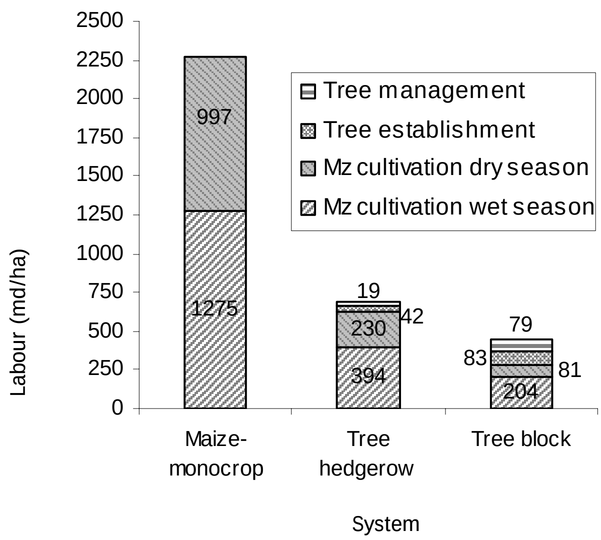

Figure 5. Labour inputs required for maize monocropping and maize - *Eucalyptus deglupta* agroforestry for a 12-year rotation period

Figures 6 and 7 present the sensitivity of LEV for maize monocropping and agroforestry to changes in maize and timber prices (100% represents the observed price), discount rate and timber yields, at the observed labour cost. Rather than just

estimating the profitability of the systems at a given value of the parameters, these graphs allow determination of the range of values that a particular parameter can take before the ranking of the systems changes (following Von Platen 1992). Combinations of maize and timber price left of the graph line indicate economic advantage for agroforestry, and combinations right of the graph line are advantageous for maize monocropping. For example, at current timber price (PhP4/bf) and low timber yield, the maize price would have to decrease by 20% before the returns from gmelina intercropping equals the return from maize monocropping, at a 20% discount rate. But if farmers are able to attain high timber yields (as indicated in Table 3), a 5% to 7% decrease in the price of maize will make timber intercropping at least as profitable as maize monocropping. Overall, the analysis indicates that for gmelina agroforestry to be more profitable than maize monocropping at a 20% discount rate, timber yields should be high or the timber price should increase by at least 50% (from PhP4 to 6/bf). One option to achieve a higher price is to grow larger trees, because market surveys showed sawmill owners to be willing to pay this price for straight logs that are at least 2.5 m long with 14 cm small-end diameter (Bertomeu 2004).

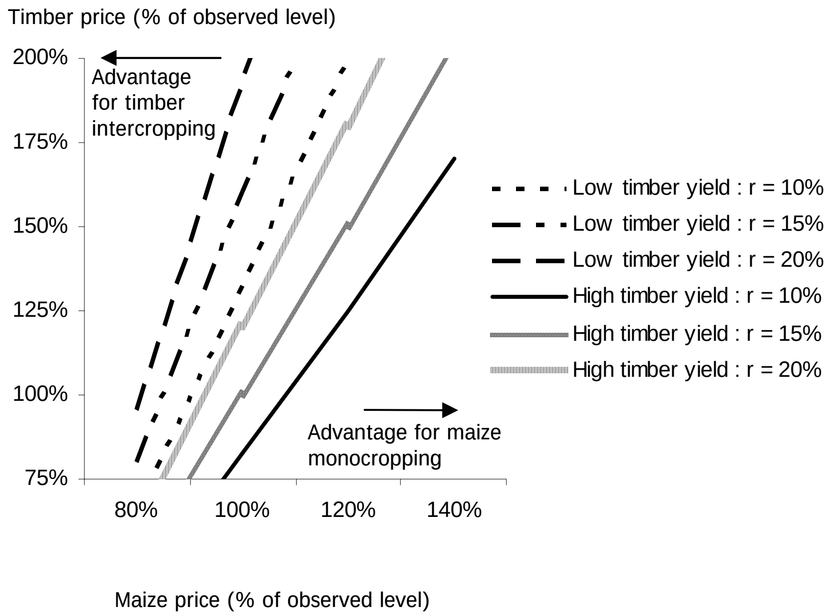

Figure 6. Break-even line of LEVs of maize monocropping and *Gmelina arborea* intercropping (labour cost as observed)

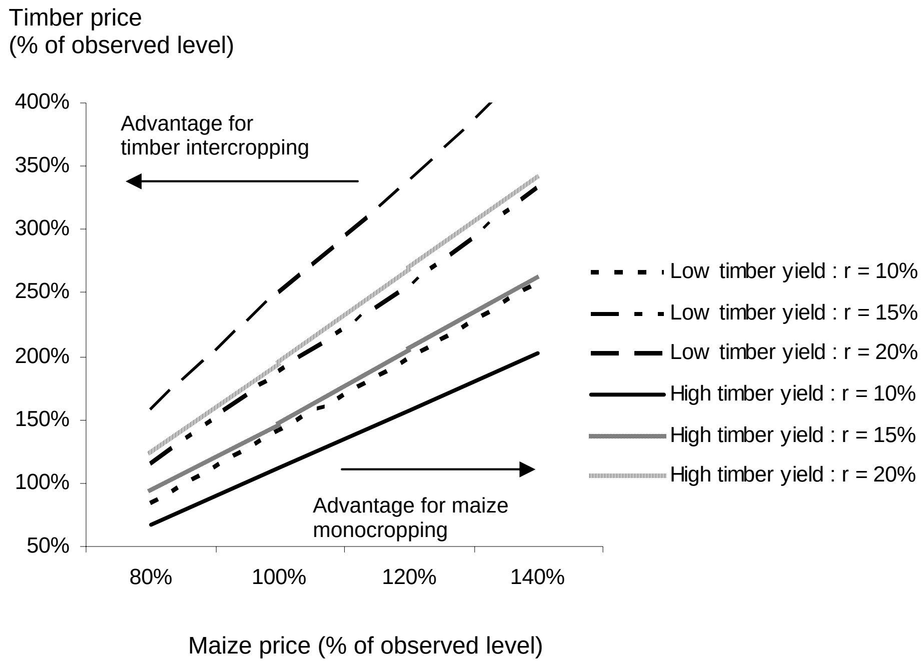

Figure 7. Break-even line of LEVs of maize monocropping and *Eucalyptus deglupta* intercropping (labour cost as observed)

Predicted financial performance of bagras agroforestry is less favourable than that of gmelina. Figure 7 reveals that if high timber yields are achieved, for tree intercropping to be as profitable as maize monocropping at the current maize price and 20% interest rate, the stumpage price would have to increase by 100% (from PhP4 to 8/bf). It should be noted however, that although a price increase of such a magnitude is unlikely to occur for gmelina (due to oversupply and lower timber quality), sawmill owners interviewed appeared willing to pay between 7 to 9 PhP/bf for bagras timber. Figures 8 and 9 present break-even lines for gmelina and bagras agroforestry, respectively, for the case when labour costs are increased by 50%. Figure 8 indicates that at the current timber price, 20% interest rate and high timber yield, gmelina agroforestry would be as profitable as maize monocropping, even if the maize price increases by 8%. In the event of low timber yields and current timber and maize prices, gmelina intercropping breaks even at a 15% discount rate. Figure 9 illustrates for bagras that if labour costs increase by 50%, with current maize price, high timber yields and 20% discount rate, agroforestry would break even only if timber price increases by 50% (from PhP4 to PhP6/bf).

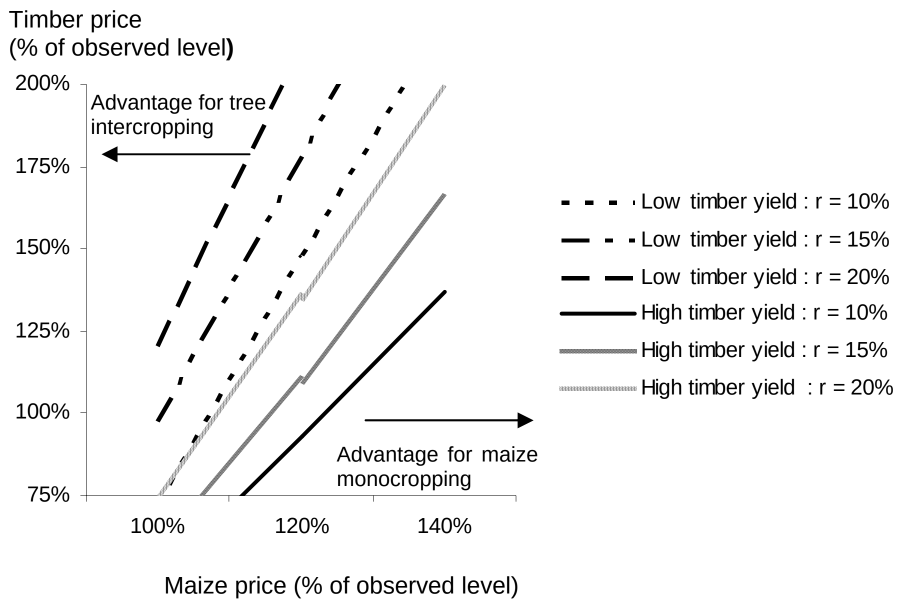

Figure 8. Break-even line of LEVs of maize monocropping and *Gmelina arborea* intercropping (observed labour cost + 50%)

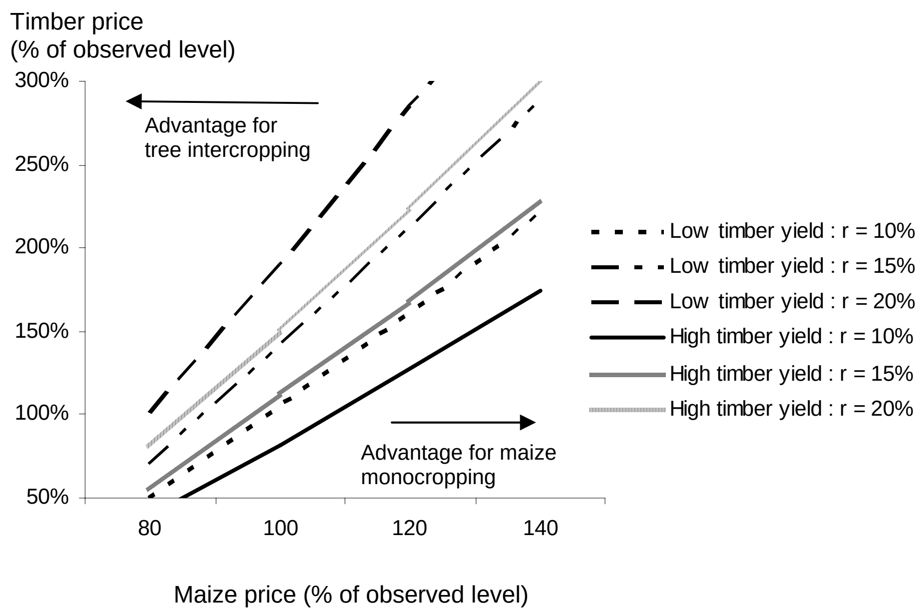

Figure 9. Break-even line of LEVs of maize monocropping and *Eucalyptus deglupta* intercropping (observed labour cost + 50%)

DISCUSSION

Financial analysis reveals that at current timber prices and with low to average timber yields, returns from maize monocropping exceed those from maize-timber intercropping. Maize-timber agroforestry systems would be more profitable if farmers were able to achieve high timber yields (as assumed in this study) or quality timber which commands a higher price. They could realise this in several ways:

a. by planting higher quality trees (i.e. producing high quality seedlings or using an improved provenance);
b. by improving management practices. On-farm trials conducted for this study show that systems with widely-spaced tree rows (10 m or more), frequent but moderate pruning and intensive management of alley crops can produce trees with the size and form required for high timber yields (Bertomeu 2004);
c. by planting other timber species that command a higher market price. For instance, mahogany will likely have a farm gate price 50% to 75% greater than gmelina;
d. by growing timber trees for high-value products (e.g. face veneer).

To achieve this, farm forestry extension programs in the Philippines need to address three broad issues. There is a need to provide high quality germplasm of a wider range of timber tree species suited to the diverse environmental and socio-economic conditions of smallholder farmers. If germplasm is made available, farmers have shown they are willing to adopt new species. Second, there is a need to demonstrate to farmers the financial gains they would derive from producing high quality timber by improving their tree management practices (i.e. pruning and thinning). A combination of on-farm trials, with active involvement of farmers in design and management, and more training can address this. Third, tree growers' access to markets can be improved by developing cooperatives that enhance the economies of scale of timber production and facilitate market information, and engaging in active dialog with government agencies to remove restrictive regulations on the use and marketing of planted trees.

Farm forestry is a more attractive option for labour and capital-constrained households or those with off-farm opportunities that compete with their labour. These farmers may raise productivity and income by establishing timber-based agroforestry systems on excess land that cannot be devoted to annual crops. Although forestry extension programs in the Philippines have typically promoted tree planting at close spacing[3] (e.g. 2 x 2 m or 3 x 2 m) (Agpaoa *et al*. 1976, Valdez 1991, Gacoscosim 1995, DENR-ERDB 1998), irrespective of whether the objective was plantation forestry or smallholder farm forestry, agroforestry systems with widely-spaced tree hedgerows (as described in this study) seem more appropriate for smallholder farmers than tree blocks. The advantages of planting trees at wider spacing in association with agricultural crops over tree blocks are the lower establishment and management costs, faster tree growth and higher timber yields,

[3] An exception is the 'line planting system' (LPS) promoted by PICOP in its tree farming scheme (Santiago 1997).

the longer period of intercropping (as in the case of bagras), and probably, higher carrying capacity for livestock during the timber fallow period. There is also evidence of this elsewhere. In Latin America, (Rodriguez 1998) as cited in (Beer *et al.* 2000) estimated that the costs of land preparation, weeding and pest and fire control were 51% to 68% lower in an intercropping system than in pure reforestation. For these reasons *Taungya*, the century-old system of reforestation in which intercropping is practiced during the first few years after tree planting, is one of the best strategies to tree establishment and survival, to reduce reforestation costs and to produce timber for farmers and the industry (Jordan *et al.* 1992, Tyndall 1996, Mayhew and Newton 1998).

More rapid tree growth, and shorter tree rotation as a result, is another benefit of planting trees in widely-spaced rows. Habiyambere and Musabimana (1990) found that the dbh of *Grevillea robusta* planted at 3 x 3 m was significantly greater than the dbh of trees planted at 1.5 x 1.5 m. Kapp and Beer (1995) showed that in response to reduced inter-tree competition and improved site conditions, the dbh of trees in association with crops at the age of 5 years was 24% (4.1 cm) for mangium and 61% (9.3 cm) for *Cordia alliodora* (laurel) greater than the dbh of trees in pure plots (3 x 3 m). Kapp *et al.* (1997) also reported that because of the excellent growth rates, mangium, laurel, bagras and *Tectona grandis* (teak) can produce timber in rotations of 10-20 years when planted on boundary lines of farms in the lowland humid tropics of Central America. And according to Beer *et al*. (2000) the growth rate of the high-value timber laurel can be exceptionally high (between 25.6 to 36.6 cm after 8 years) if grown in optimal conditions of drainage, weed control, fertilization, and wide spacing.

Another financial analysis of tree plantations in the Philippines (DENR-ERDB 1998) suggests a higher NPV and benefit/cost ratio (BCR) than the agroforestry systems of this study. For a plantation of gmelina with an 8-year rotation period, the DENR estimated at 15% discount rate a NPV of US$2641, whereas in this study, the NPV (15%) of gmelina hedgerow intercropping is US$1131. Similarly, for bagras, harvested at 8 years, DENR reported a NPV (15%) of US$5404, whereas this study found a NPV (15%) of US$1846 for tree hedgerow intercropping with a 12-year rotation. However, the major reason for the large difference between these financial calculations is the DENR timber price of PhP9/bf (US$95.4/$m^3$) for gmelina timber and PhP10.5/bf (US$111/$m^3$) for bagras, which are more than twice the current average price of farm-grown gmelina. In addition, DENR's study assumed a profitable intermediate thinning generating US$3750/ha, which is probably overoptimistic.

It should also be noted, however, that intercropping systems with widely-spaced trees are not always productively superior to tree blocks or monocultures. In linear agroforestry systems, more branching and poor stem form due to less lateral competition may reduce timber production. Peden *et al.* (1996) found that trees planted in lines are unlikely to produce high quality commercial poles under short rotations. When high quality timber is required, it is difficult to assess the extent to which improved management can substitute for a better light regime in line planting systems. Labour-constrained households may not be able to meet higher labour demand for tree pruning required to produce trees of acceptable quality. In addition, as this study has shown, some trees, particularly fast-growing timber trees, are so

competitive that even if planted in widely spaced rows, the association with annual crops would jeopardise household food security. Confronted with the dilemma of whether to integrate trees and crops and if so, what level of mixture is appropriate, farmers may opt for segregation whenever mixed systems do not prove superior in terms of feasibility, financial profitability and food security.

In spite of these caveats, agroforestry systems with widely-spaced trees have the potential of diversifying farm production, of producing higher economic returns, and providing other economic and environmental benefits derived from tree planting, including erosion control, soil fertility improvement and windbreaks. In Claveria, many farmers who have experienced timber tree growing in the recent past are still interested in timber tree production, in spite of lower timber prices in recent years. About 76% of experienced tree growers interviewed during a farm survey recommended that future plantings of timber trees should be done at densities of about 834 sph and some even suggested densities as low as 400 sph (Magcale-Macandog *et al.* 1999).

LIMITATIONS OF THE ANALYSIS

The profitability of timber-based agroforestry systems was studied using data from researcher-designed and managed on-farm trials with a small number of replications. These provided limited information about the variability of key parameters (labour, yields, farm management costs and farmer management practices). Ideally, financial analysis should have been undertaken with data over a broad range of farm types (20 to 50 farms) which better reflects some of the variability in inputs (e.g. labour), and outputs (grain and timber yields), allowing capture of the uncertainty for farmers by performing a separate financial analysis for each replication and examining the variability of net returns (Franzel *et al.* 2002). Unfortunately, this was not possible due to time and resource constraints.

Another limitation of the study is the way in which tree taper, and thus merchantable volume, has been estimated for bagras. Taper rates have been extrapolated from the lower 2.4 m of the bole at age 4 to estimate taper in 12-year old trees with a merchantable height up to 17 m. Although no major difference was observed between the taper of the lower 2.4 m bole of 4-year old gmelina trees, and the taper of mature trees measured at sawmills, generally rates of taper can vary substantially along the bole and over the life of an individual tree. Future studies should, therefore, consider this.

The study is also limited in scope in that it has valued only the main products – maize grain and timber – and environmental and other less tangible benefits derived from tree planting (e.g. erosion control or boundary demarcation) are not included[4]. Also, other products with a direct market value (e.g. fuelwood and poles from intermediate thinnings) are not included in the analysis. A previous survey found that household use and marketing of these by-products from planted timber trees is limited by the abundance in the area of other sources of fuelwood (e.g. coffee

[4] For such a study in Claveria, see Predo (2002).

branches, bamboo stakes and maize cobs) and of poles (e.g. from naturally regenerating trees) (Bertomeu 2004).

CONCLUDING COMMENTS

In northern Mindanao, the Philippines, widespread planting of a few fast-growing tree species has led to oversupply and a drastic decline in the price of farm-grown timber. Financial analyses indicate that while the current timber price prevails, maize monocropping will be more profitable than maize-timber intercropping. Only if high timber yields are achieved, or in the event of a substantial timber price increase, would timber intercropping be more profitable than maize monocropping. Thus, to increase the financial returns of farm forestry in the Philippines, it is imperative for tree farmers to either diversify tree production by planting other high quality timber species that fetch a higher market price, or grow larger trees intended for high-value wood products.

Higher returns to labour from intercropping systems, as compared to maize monocropping, suggests that farmers with scarce labour and capital would increase their income by establishing timber-based agroforestry systems on excess land. Timber intercropping would also be more financially attractive than maize monocropping in the event of an increase in farm labour wage. The on-farm trials conducted in this study showed that intercropping systems with widely-spaced tree hedgerows are appropriate to produce logs of the size and form required by the wood industry. For many small upland farmers in the Philippines, integrating widely-spaced tree hedgerows in their farming systems is a feasible option to generate income and other benefits derived from planted trees, while supplying scarce timber to the local wood industry.

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